爱因斯坦探针
einstein probe

EP Performance Verification (PV) Targets Recommendation Form

Submission Due Date: 15th October 2023

NOTE: Please do not change or delete the words marked in blue.

1. TITLE

AGN Variability at the South Ecliptic Pole

2. ABSTRACT *(< 250 words)*

(summarize the target properties, the EP capabilities to be verified, and justify why the proposed observations and targets should be considered for the PV phase)

We propose a FXT target of the south ecliptic pole (SEP), with LMC covered by WXT at the same time. Across the whole sky, the ecliptic poles are the only positions with whole-year visibility (away from the sun) and thus the best choice for month-scale continuous monitoring. The eROSITA all-sky survey (eRASS) performed the best high-cadence (4h), long-term (~800days), continuous monitoring of a sample of AGN at SEP. The eROSITA-SEP catalog (Liu et al. in prep.) is a good reference for the test of deep FXT surveys composed of multiple exposures. The eRASS monitoring of SEP produced valuable X-ray variability data, particularly at high frequencies, but was unluckily interrupted at a total length of 2.3 years. An FXT low-cadence long-term monitoring of this field could complete the low-frequency part of variability and thus make a precious data set of AGN with high-quality PSD, which is highly valuable for the AGN community. As a pre-study of the long-term SEP monitoring, we propose this PV mini project as a FXT test of multi-exposure survey in the low-flux regime, which is also very helpful in AGN science because it narrows down the gap between eRASS and future observations and leads to a chance of new findings in X-ray variabilities by comparing eROSITA and FXT data. The WXT data of LMC obtained at the same time also add to the LMC monitoring of STP4.

3. RECOMMENDERS' INFORMATION

Principal Recommender	
***Recommender' Name**	Jun-Xian Wang

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***Recommender' Email Address**	jxw@ustc.edu.cn
***Recommender' Expertise**	Jun-Xian Wang is an expert in AGN and X-ray astronomy
***Recommender' STP(s)**	STP1
Co-Recommenders	
***Recommenders' Names**	Teng Liu Chandreyee Maitra (STP4)
***Recommenders' Email Addresses**	liuteng@ustc.du.cn cmaitra@mpe.mpg.de
***Recommenders' Expertise**	Teng Liu is an expert in AGN and X-ray survey, and has led the eROSITA SEP AGN survey. Chandreyee Maitra (MPE) is an expert in LMC XRB.
***Recommenders' STP(s)**	STP1 (JXW, TL) STP4 (CM)

4. TARGET FORM

- **TARGET 1** ***(mandatory)***

***Target Name**	SEP & LMC			
***Target Type**	AGN & XRB			
***Target Coordinates**	***RA:**	90.0	***DEC:**	-66.5607083
***Expected Flux in 0.3-10 keV**	Multiple sources 5e-14 ~ 5e-10 erg/cm^2/s			

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***Primary Instrument**	FXT (and WXT)			
FXT Configuration ***(mandatory if the primary instrument is FXT, optional if the primary instrument is WXT)***	**FXT-A**	Full-frame Thin filter (choose filter between *thick* and *medium* filter; can be different from FXT-B)	**FXT-B**	Full-frame Thin filter (choose filter between *thick* and *medium* filter; can be different from FXT-A)
***Exposure Time**	25 minutes every day in 7 days In total 10.5ks			
Suggest Joint Observation with Other X-ray Telescopes	No			
Other remarks	(any other remarks)			
*Note: * mandatory items*				

- **TARGET 2 and more…**
  (optional, if there are more than one target in this recommendation, copy the entire target form above to the empty space below; note that this is only for the case that one observing proposal includes multiple targets; for targets of a different proposal with distinct technical and scientific goals, please submit them in separate proposals.)

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5. SCIENTIFIC AND TECHNICAL JUSTIFICATION
(< 2 pages in total for this session, including figures, tables and references)

- **Scientific Motivations and Values**

  FXT long-term, continuous, pencil-beam monitoring, or in another word, deep survey, could reveal rich information of a large sample of distant AGN. Such a survey was achieved by eROSITA in the region around SEP. During the eRASS survey (2019.12-2022.02), it was continuously monitored for ~800 days with a high cadence of every 4 hours, reaching a total exposure time of 160ks. Such a long, continuous, high-resolution, X-ray monitoring is unique in X-ray astronomy, making SEP (the other pole NEP is similar) a particularly important region for the study of AGN X-ray variability. The eROSITA monitoring was unluckily interrupted in Feb. 2022 at a length of 2.3 years, limiting its capability of studying long-term variability (year scale) of AGN. FXT should take up the baton of monitoring SEP and NEP, because these two poles are the only positions with whole-year visibility and this is the most efficient and economic chance to create a legacy survey of AGN with high quality variability measurements at a wide range of time scales. We will propose long-term FXT monitoring of SEP (low cadence) and NEP (low/medium cadence) as a regular observing program. NEP needs a higher cadence because we will use the 2.5m WFST telescope to monitor it simultaneously. For now, we propose a 7-day PV monitoring of SEP as a pre-study of future SEP/NEP monitoring projects.

  This mini survey works as FXT performance verification in detecting and analyzing faint X-ray sources with multiple exposures. The eROSITA SEP AGN survey, led by Prof. Teng Liu, provides not only a high-quality X-ray catalog, but also well-studied X-ray light curves, spectra, multi-band counterparts, and optical spectra. This field contains not only a large number of AGN but also some candidates of transients and TDE. Considering the similarity of characteristics between eROSITA and FXT, the eROSITA SEP survey is a perfect reference for testing the imaging quality, source detection, and spectral/variability properties in the case of multiple-exposure, deep surveys with FXT. Meanwhile, although very short, this observation might still lead to new findings by combining the PV data with the data of eRASS. Observing SEP during PV is also helpful in the sense that it narrows down the gap between eRASS and future observations.

  SEP is not only important for AGN science, it is also a highly economic PV target that takes advantage of both FXT and WXT. SEP is located at the border of LMC. Targeting FXT at SEP, LMC is basically covered by WXT. Containing a number of bright/variable XRB, LMC has always been an interesting target of X-ray monitoring and has contributed many findings in X-ray variabilities. LMC contains a few superbright X-ray sources that were detected since the early age of X-ray astronomy, namely LMC X-1, X-2, X-3, and X-4, which guarantee suitable targets for WXT and can be used to test the WXT alert algorithm. The HMXB pulsar LMC X-4 shows a lot of interesting variability features, like QPO (Rikame+2022), spin-torque reversal (Molkov+2017), pulsation dropout and turn-on (Brumback+2018). Particularly, an

outburst was detected in it by LEIA (Li+2023). LMC also hosts numerous BeXRBs which can reach Lx ~$10^{36\text{-}38}$ erg/s when go into outbursts, and can be captured by WXT.

- **EP Capabilities to be Verified**
  (briefly describe the capabilities that can be verified by the recommended targets and observations. For example: this target can demonstrate WXT's imaging capability of large field-of-view and sensitivity)

  1. Deep survey capability (imaging quality, source detection) of FXT combining multiple exposures
  2. Onboard alert algorithm reaction to WXT detected bright, variable XRB
  3. FXT light curve quality of faint SEP sources
  4. WXT light curve quality of bright LMC sources

- **Immediate Objectives**
  (listed the main objectives of the recommended targets and observations)

  1. Combine multiple FXT exposures of SEP, perform source detection, and compare the catalog and source properties with that of eROSITA
  2. Combining eROSITA and FXT light curves to study AGN variability and look for AGN ignition, shutting down, or changing look and other interesting sources
  3. Based on the results, design the regular SEP/NEP monitoring program.
  4. Test WXT data quality of bright LMC sources and algorithm reaction to their variability.
  5. Study X-ray variability of bright LMC XRB with WXT.

- **Technical Justification (e.g. target visibility during the PV phase)**
  (briefly justify the technical feasibility of the recommended target and observation, such as the target visibility during the PV phase, brightness, variability, etc.)

  The two ecliptic poles are the only positions that are almost always visible.
  The four bright LMC sources (X1~X4) are located with a distance of 3~6 deg from SEP and thus can be covered by WXT.
  The effective area of FXT is approximately 1/6 of eROSITA. To reach the light curve quality of eROSITA, which observes SEP for 4 minutes every day, we need 24 minutes FXT exposure every day.

- **References**
  (list relevant references for the recommended targets and observations)

Discovery of quasi-periodic oscillations in the persistent X-ray emission of accreting binary X-ray pulsar LMC X-4
Discovery of Pulsation Dropout and Turn-on during the High State of the Accreting X-Ray Pulsar LMC X-4
Near-periodical spin period evolution in the binary system LMC X-4
LEIA detected a bright outburst from LMC X-4

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